Be it known that Salman M. Kassir has invented a new and useful

Method of Spin Etching Wafers with an Alkali Solution

of which the following is a specification:

Field of the Inventions

The methods and devices described below relate to the field of integrated circuit manufacture.

Background of the Inventions

To build an integrated circuit chip, a layer of selected materials is deposited on a silicon substrate using a variety of deposition techniques, including chemical vapor deposition, sputtering, ashing, and other techniques. Chemical mechanical planarization (CMP) usually is performed after depositing the layer. CMP provides smooth, planar topographies to semiconductor wafers and surfaces deposited on a semiconductor substrate, such as silicon, and is an integral part of making many types of integrated chips. The deposition and polishing steps are repeated as necessary to build a multi-layer integrated chip. For example, a layer of electrically conducting material is sputtered onto an etched substrate. The CMP process then is used to remove the layer until the electrically conducting material remains only in the etched areas. Subsequently, additional layers are added and then polished until the final product is achieved: many layers of integrated circuits on the built-up front side of the silicon substrate.

When building integrated chips it is important that the semiconductor substrate be very thin, as thin as 100 micrometers or even 75 micrometers (μm). To make the substrate as thin as possible, and to relieve stress caused during the deposition and CMP processes, the back of the wafer is ground to remove the bulk of the substrate. This process is known as backgrinding. However, stresses build up during the backgrinding process that tend to warp the wafer and make it vulnerable to breaking when the wafer is later cut into individual die. The stress is caused by small deformations on the surface of the substrate, typically grind lines, that arise from the physical force of grinding. In addition, the stress caused by backgrinding is exacerbated by internal stresses accumulated during the layer building process. Thus, it is important to relieve as much wafer stress as possible.

Currently, wafers are wet-etched with acid etchants to relieve stress after backgrinding. However, wet etching with acid poses four significant problems. First, the acid may damage the outer edge of the top layers of the wafer if the acid seeps through the protective means, such as backgrind tape, used protect the front side of the wafer. The damage can destroy integrated chips located around the edge of the wafer, thus reducing production efficiency. Second, using acids is inefficient. Wet etching with acids requires that the background wafers be transferred to a separate machine built to withstand the acids. The time required to transfer the wafers and conduct an additional process reduces the efficiency of chip production. In addition, a machine that can perform wet etching with acid is very expensive, both initially and operationally, thus making the process more expensive and less efficient. Third, transferring fragile wafers to a separate machine while the wafers are at a maximum state of stress increases the

probability of damaging the wafers, thereby further reducing efficiency and increasing the cost of production. Fourth, the acids typically used in the etching process are environmentally toxic and difficult to dispose of properly. The cost of the acids, plus the cost of disposing of the acids, make the cost of using an acid wet etch process even more expensive. Thus, a new method for reducing wafer stress has been developed in order to avoid unnecessary damage to the integrated chips on the front side of the wafer, increase efficiency, reduce cost, and reduce environmental pollution.

Summary

The methods and systems described below provide for a more efficient, a less expensive, and easier stress relief process after backgrinding. Instead of using acids to perform stress relief, the wafers are placed onto a spinning platform in a chamber used for the normal rinse step of the backgrinding process. A solution of potassium hydroxide (KOH) is then sprayed onto the substrate side of the wafer while it is spinning. The KOH solution performs the substrate removal necessary to reduce surface stresses in the wafer, while spinning the wafer ensures that the substrate removal is evenly distributed. After spin etching is completed the wafer is rinsed and then moved to the next processing step.

Brief Description of The Drawings

Figure 1 is a block diagram of a system for producing integrated chips, including the backgrinding step and the step of spin etching the backside of a wafer with an alkali etch solution.

Figure 2 illustrates a cross section of a silicon wafer upon which a plurality of layers has been deposited.

Figure 3 illustrates the warping that can occur in the wafer of Figure 2 if the stresses in the wafer are not relieved.

Figure 4a shows the wafer of Figure 2 further magnified to illustrate bottom surface warping caused by backgrinding.

Figure 4b illustrates the wafer after a portion of the bottom surface of the substrate has been removed.

Figure 5 illustrates the process of backgrinding an integrated chip substrate.

Figure 6 illustrates the methods and systems used to perform spin etching with an alkali solution to achieve wafer stress relief.

Figure 7 is a schematic of the rinse station of a modified version of a Strasbaugh 7AF Intelligent Wafer Grinder.

<u>Detailed Description of the Inventions</u>

Figure 1 is a block diagram of a system for producing integrated chips, including the backgrinding step and the step of spin etching the backside of a wafer with an alkali etch solution. In step **1** silicon is purified and cast into electronic-grade ingots. The ingots are then converted into high purity, single crystal silicon by growing a crystal silicon structure. In step **2** the ingot is sliced into wafers using a diamond saw, with each wafer being approximately 1/40″ thick. In step **3** each wafer is polished, lapped smooth, damage decorated with acid to reveal hidden defects, and may be ground either over the wafer surface or at its edges. After the polishing processing, also known as wafering, is complete the

new prime wafer is ready to have integrated circuits built upon it. In steps **4** and **5**, integrated circuits are built onto the front side of the wafer. In step **4** at least one layer of material is deposited onto the silicon wafer substrate. Then, in step **5**, a CMP process is applied to the layer in order to ensure a very flat surface, to enhance photolithographic abilities, to improve metal wiring quality, to enhance step coverage, and to realize other advantages. The result is many integrated circuits deposited on a silicon substrate. Steps **4** and **5** are repeated as necessary until the desired number and types of layers are reached and a complicated plurality of integrated circuits is built up on the front side of the wafer. In step **6** the bulk of the silicon substrate is removed from the back side of the wafer in a process known as backgrinding. Backgrinding makes the overall chip thinner, thus allowing better heat dissipation in the finished integrated circuit chip. However, backgrinding adds surface stress to the wafer, thus making the wafer more prone to warping.

In step **7** the wafer is processed to relieve surface stress on the backside of the wafer. In this step, the wafer is spin etched in an alkali etchant. We apply an aqueous solution of potassium hydroxide (KOH), or other base or alkali etch solution, to a spinning wafer in a gaseous environment. The KOH spin etching method removes a sufficient portion of the substrate layer to relieve the stress in the wafer.

In step **8** the newly etched wafer is rinsed and dried. It is also inspected for unwanted defects. In step **9** the wafer is cut into individual die. Each die is an individual integrated circuit chip. Each die is then processed by attaching wires to pre-determined locations on the integrated circuit chip. In

step **10** the new integrated circuit chips are tested and then encapsulated into ceramic or plastic enclosures.

Figures 2 through 4b illustrate the principles of the stress reduction step represented by block **7** in Figure 1. Figure 2 illustrates a cross section of a wafer **16** and the front side **17** of a plurality of layers **18** which have been deposited on a silicon substrate **19**. The CMP process has made the surface **17** of the wafer **16** planarized and smooth. Backgrinding has removed much of the original thickness from the back side **20** of the silicon substrate **19**. However, the physical force used during backgrinding causes surface stress to build up along the bottom surface **20** of the wafer **16**.

Figure 3 illustrates the warping that can occur due to these stresses when the silicon substrate **19** and overall wafer **16** become very thin. The bottom surface **20**, top surface, **17**, and layers **18** become non-planar, rendering the wafer useless for most applications. Spin etching with an aqueous solution of KOH after backgrinding will relieve surface stresses along the bottom surface **20** of the wafer **16** and thereby avoid this warping.

Figure 4a shows a magnified cross-section of the wafer **16** shown in Figure 2 and illustrates the non-planar bottom surface **20** of the substrate **19** remaining after backgrinding. The warping is reduced by chemically removing a portion of the bottom surface **20**. The demarcation line **21** shown in phantom illustrates the portion of substrate that is removed (the portion removed is below the phantom line **21**). By removing the irregular surface of the substrate 19 the overall stress in the wafer **16** is reduced. Note that the degree of warping shown is exaggerated in comparison to the total thickness of the wafer. The backgrinding process typically grinds a 700 micrometer (μm)

substrate to a thickness of from about 250 µm to about 75 µm. On the other hand, the amount of silicon removed from the back side **20** of the substrate **19** by etching is typically from about 0.1 µm to about 2 µm.

Figure 4b illustrates the wafer **16**, including the deposited layers **18**, after a portion of the bottom surface **20** of the substrate **19** has been chemically removed. The surface stress on the wafer is now greatly reduced. Because one of the major sources of stress has been significantly reduced, the wafer is much more stable and is much more likely to retain its shape.

Figures 5 through 7 illustrate methods and devices by which a wafer is background and subsequently spin etched with KOH. Figure 5 illustrates the process of backgrinding an integrated chip substrate **19** in a grinding chamber **23**. First, the wafer's front side **17**, comprising the multiple layers of deposited material **18**, is secured to a work chuck **24** by means of a vacuum. Backgrind tape may be placed on the front side of the wafer to protect it during handling, during the grinding step, and during the etching step. Subsequently, the grinding wheel **25** grinds the back side **20** of the wafer and removes the bulk of the silicon substrate **19** as the work chuck and grind wheel rotate on spindles **26**, as shown by arrows **27**. After backgrinding, a robotic arm typically transfers the wafer **16** to another work chuck in a separate rinse station.

Figure 6 illustrates the methods and systems used to perform spin etching with KOH to achieve stress relief. The spin etch process is performed in the same rinse chamber **28** used to rinse the wafer **16** after backgrinding. However, the rinse chamber is coated with Teflon©, or a similar non-reactive or corrosive-resistant material, to protect the chamber from the corrosive effects of KOH.

The center of the front side **17** of the wafer **16** is secured to the relatively narrow work chuck **24** by means of a vacuum. The back side **20** of the wafer is then rinsed with de-ionized water (DI water) **29** while the wafer **16** rotates about the axis of the work chuck **24**, as shown by arrow **30**. After rinsing, the back side **20** of the wafer is sprayed with a warm alkali etching solution **31**, typically KOH, while the wafer **16** continues to rotate. The warm alkali solution removes a portion of the substrate **19**, thus relieving stress in the wafer **16**. While the alkali solution is applied to the back side **20** of the wafer, the front side **17** of the wafer **16** is simultaneously sprayed with chilled deionized water **32** at a temperature of about 5° Celsius to about 15° Celsius. The chilled deionized water is sprayed from a plurality of nozzles, or injection ports, disposed within an annular nozzle platform **33**. The nozzle platform **33** is supported by a support **34**. The distance between the nozzle platform **33** and the wafer **16**, shown by arrows **35**, can vary, but is typically about 1 millimeter. The chilled water keeps the wafer **16** cool, thus protecting it from the relatively high temperature of the alkali solution. Furthermore, the chilled water protects the front side **17** of the wafer **16** from direct contact with the alkali solution.

The bulk of the alkali solution and cooling water is thrown outward by the centrifugal force caused by spinning the wafer and the mixture of waste alkali solution and waste water is drained away into a waste or recycle tank. The rinse station's exhaust system then collects much of the remaining residue of alkali solution thrown from the wafer. After the etching process is complete, both the backside **19** and front side **17** of the wafer **16** are given a secondary rinse of de-ionized water to remove any remaining alkali solution. The wafer **16** is then dried by blowing air from the bottom of the chamber while

spinning the wafer at a rate of about 2000 RPM to about 4000 RPM. Finally, the wafer is transferred from the rinse and etch chamber to the next stage of wafer or chip processing.

To remove the required amount of substrate a solution of from about 20% to about 40% of KOH at a temperature of about 55° Celsius to about 85° Celsius is sprayed onto the back side **20** of the silicon wafer **16** at a rate of about 100 milliliters per minute (ml/minute) to about 500 ml/minute for about 1 minute to about 5 minutes. In order to ensure that the substrate is chemically removed to an even depth, the silicon wafer is spun at a rate of about 20 RPM to about 500 RPM: typically in the range of about 20 RPM to about 50 RPM. The centrifugal force of spinning causes the KOH solution to spread evenly across the back side **20** of the wafer **16**, prevents the KOH from building up in relatively low areas on the substrate, and ensures that relatively high areas on the substrate are worn down preferentially. At the same time that the KOH is applied to the backside **20** of the wafer **16**, the front side **17** of the wafer **16** is sprayed with deionized water **32** chilled to a temperature from about 5° Celsius to about 15° Celsius.

As an alternative to using the vacuum chuck described above, the wafer **16** may be secured to a rotatable chuck which supports the entire front side of the wafer, such as the chuck shown in Figure 5. In this case, the wafer is secured to the chuck with backgrind tape, which may be the same backgrind tape used to secure the wafer during the backgrind process. Thus, it is possible to design a machine that performs the backgrind, rinse, and alkali spin etch steps all in the same chamber of the same machine. Whichever chuck to which the wafer is secured, only the back side **20** of the wafer **16** is exposed to the KOH during the spin etch process. The front side of the wafer is

then cooled by directly cooling the chuck in a water bath or by thermal coupling to some other heat sink. In the case of a water bath, the wafer is secured to the chuck by a vacuum while water is circulated underneath the wafer. The circulating water directly contacts the front side of the wafer, though the level of the water is carefully controlled to prevent it from touching the backside of the wafer while spin etching is performed.

Whichever version of the chuck is selected, either that exemplified in Figure 5 or that exemplified in Figure 6, the chuck is designed such the wafer **16** need not leave the rinse station chuck **24** between the rinse, spin etch, and secondary rinse steps. Thus, the overall efficiency of the process is increased.

Figure 7 is a schematic of the rinse station of a modified version of the Strasbaugh 7AF Intelligent Wafer Grinder, a machine used to perform backgrinding and other wafer grinding applications. Although a modified version of the Strasbaugh 7AF Intelligent Wafer Grinder is used to illustrate the methods described below, the methods are not dependent on that machine. The methods could be used in nearly any machine used to rinse wafers. Alternatively, the method could be used in a machine separate from the one used to perform the rinse step, as is typically done for acid etching methods.

After backgrinding, the wafer **16** is rinsed with de-ionized water pumped from a de-ionized water tank **36** by a pump **37** through a DI water valve **38** and ultimately through a nozzle **39**. The de-ionized water removes small particulates left behind during the grinding process. In order to ensure that all of the particulate matter is rinsed away, the wafer **16** is spun on a platform **40** as shown by arrow **41**. The waste water then falls through the rinse station drain **42**. The KOH drain valve **43** is

closed and the water drain valve **44** is opened so that the waste water drains away into the waste water tank **45**.

After the rinse step the KOH drain valve **43** is opened and the water drain valve **44** is closed. Then, KOH is pumped by a pump **51** from a KOH tank **52** through a KOH valve **53** and finally through a KOH nozzle **54** onto the spinning wafer **16**. The excess KOH flows through the rinse station drain **42** and back into the KOH tank **52** where the KOH is recycled. Waste material etched from the wafer **16** will settle to the bottom of the tank and thus will not interfere with the etching process. Periodically, typically every few days, the KOH tank **52** will be drained and fresh KOH will be placed in the tank **52**. Alternatively, the KOH is not recycled. In this case, the KOH is delivered from a separate KOH tank. The waste KOH is then drained through the rinse drain **42**, through the KOH drain valve **43** and into a waste tank, where the waste KOH is stored before it is eliminated.

Although using a KOH solution on a spinning wafer is useful to remove a portion of the substrate on thin wafers, the method is also useful in other applications. For example, the method is useful for damage decoration, for etching wafer layers, for removing material on prime wafers, and for revealing hidden defects on prime wafers. The process also is useful on wafers using substrates other than silicon, such as gallium arsenide. In addition, other basic and alkali solutions can be used to perform the spin etch process, such as sodium hydroxide, aqueous ammonia, ammonium hydroxide, alkali metal hydroxides, or organic alkali solutions such as trimethyl ammonium.

Thus, while the preferred embodiments of the devices and methods have been described in reference to the environment in which they were developed, they are merely illustrative of the principles of the inventions. Other embodiments and

configurations may be devised without departing from the spirit of the inventions and the scope of the appended claims.